Fall 2017

Shift to Fire Creation: Flint-Knapping as Potential Fire Creation

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SHIFT TO FIRE CREATION: FLINT-KNAPPING AS POTENTIAL FIRE CREATION

by

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A thesis submitted in partial fulfillment of the requirements
for graduation with Honors in the Anthropology

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Fall 2017

All requirements for graduation with Honors in the
Anthropology have been completed.

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Abstract

This research examines the possibility of unintentional percussion fire origins through stone tool creation. I hypothesize that accidental fires created from percussion in flintknapping are a viable possibility for humans' shift from fire-control to fire-creation. This shift to the ability to create fire is not well understood, as there are few very old fire sites, and those are not firmly dated, and are not clearly determined as natural, controlled, or created. Better understanding this shift allows a greater understanding of the behavioral and evolutionary history of the human lineage. Methodology for this investigation included the use of Olduwan flint-knapping, the same technique used by early humans at the accepted time of first fire creation. The sparks created in this manner were graded on a four-point scale to quantitatively determine the likelihood of accidental fire creation during flint-knapping, with the results indicating that percussive origins were not likely.

Introduction

The origin of humans' ability to create fire is not well understood. There is not a specific time frame for this discovery, nor is there a clear consensus on how this ability was discovered. As the majority of early fire sites cannot definitively be determined as natural, controlled, or created, anthropologists cannot state with certainty when the creation of fire began to be a widespread phenomenon. Additionally, the lack of fire making tools present at many sites also leaves anthropologist unsure of exactly how early humans created fires. There is support for fires created by wood on wood friction and fires created by stone percussion. The ability of early humans to create fire is anthropologically significant, because it will have represented a shift in human behavior and, according to some research, a shift in human evolutionary patterns. This research aims to aid the overall understanding of this topic by determining the feasibility of accidental stone percussion fire creation through stone toolmaking. By determining whether or not fire creation in this manner is feasible, a narrower time range for the onset of widespread fire creation can be determined, and potential clarification of whether a number of fire sites were created by humans may be possible.

This thesis identifies existing evidence for early human fire creation in order to determine the context in which this discovery arose. An analysis of the methods of friction fires and percussion fires led to experimentation with percussion fires using pyrite and flintknapping methods. These experiments were assigned quantifiable averages to be compared with the averages of control fires, started with flintsteel rods. This research is meant to determine whether or not human fire creation may have been an accidental result of stone toolmaking.

Background

In anthropology, there are two schools of thought regarding fire and its significance to humans. One opinion is that the control of fire resulted very far back in time in the human lineage, upwards of 1.5 million years (Ma) ago, while the other suggests that humans' control of fire was much more recent (Sorenson, 2012). Supporters of the first theory cite Koobi Fora, Kenya (1.6 Ma) and Swartkrans, South Africa (1.5 – 1 Ma) as evidence of controlled hominin fire use (Brain & Sillent, 1988; Burton, 2009). Evidence of fire at Koobi Fora consists of reddened sediment indicative of heating 200-400 degrees Celcius, which is consistent with temperatures of modern campfires, and hotter than those of natural grass fires, though there is no other direct evidence supporting that humans created this fire (Burton, 2009). Evidence at Swartkrans includes burned bones, some of which had cut marks that were likely created by early human tool use (Brain & Sillent, 1998). Supporters of these early dates propose that fire acted as revolutionary force in human evolution, both physically and culturally; it changed the diet and digestive system by allowing, and subsequently requiring, food to be cooked, acted as protection against predators, and extended activity into the night hours (Goudsblom, 1992; Wrangham, 2009). Though both sites are well-known, the argument that early humans created these fires is heavily contested. The sites are widely regarded as anomalous, are much older than other sites with evidence of controlled use of fire. Further, beyond the estimated temperature of the fire, it is difficult to distinguish among the possible explanations of how the fire originated: humans created the fire, humans utilized natural fire, or the fire was caused entirely by natural processes, such as grass fire. Because of this, the study of the origins of human fire control relies on interdisciplinary studies of archaeological evidence and human evolutionary history.

The alternate perspective supports human fire control later in the evolution of the lineage, which is more easily supported by archaeological evidence (Burton, 2009). Typically, sites that are thought to be controlled use of fire date to around 700 thousand years (ka) ago or less have been suggested (Sorenson, 2012). One of the earliest sites argued to have later control of fire is Cave of Hearths in South Africa, which dates between 700 – 200 ka. However, even here evidence from the burn deposits cannot definitively be attributed to human activity (Sorenson, 2012). Examples of less controversial sites with evidence of early fires include Kalambo Falls in Zambia, dated 110 – 61 ka (Sorenson, 2012). Here, evidence of charred logs, abundant charcoal, and carbonized plants remains more clearly support human-produced fire (Sorenson, 2012). This perspective still accepts fire as a revolutionary force in human history, but focuses less on evolution and more on technological advancement. According to this theory, human physiology and activity patterns will have remained more or less the same before and after the development of the ability to control fire. For example, the ability to cook food would have presented a cultural shift to cooking food, rather than an evolutionary change requiring a total dependence on cooked food. Changes that resulted from a more recent ability to use fire would have had a much less significant role in the evolutionary history of the lineage than in the alternative theory.

Despite the differences in the two opposing theories, both make an important distinction between the ability to control fire and the ability to create fire. It is widely accepted that before they could create fire on their own, early humans were opportunistic fire users, using fire for cooking, hunting, and keeping warm by collecting fire from natural sources such as grass fires or lightning strikes (Gowlett, 2016). Control of fire refers to this ability to use fire found in nature for an intended purpose. This form of fire use long-predated the ability to create fire, and the timing of its origin in human evolutionary history is what is often debated in the two aforementioned theories. Fire control includes the use of fires that were carried from one location to another, typically in the form of an ember, which could be rekindled into full fires upon arrival at a destination (Gowlett, 2010). As long as the source of the fire was natural, rather than human-made, its use is considered the control of fire.

The creation of fire is the occurrence and use of fire that has been created by humans, rather than found in the natural world. Though it is widely accepted that the shift to fire creation occurred later in human history, most likely in the last 500 ka, and probably with anatomically modern humans or Neanderthals, there is little archaeological evidence to allow for a confident estimate of a narrower time range for the occurrence of this shift (Burton, 2009; Sorenson, 2012; Wrangham, 2009). Also unknown is how this change occurred. This shift from control of natural fire to fire created at will by humans represents what is arguably the most important technological step since the first use of fire, potentially 1.6 Ma prior, according to more liberal estimates, such as those of Koobi Fora (Burton, 2009).

Understanding how this change from fire control to fire creation occurred can grant us an improved understanding into the conditions and the lives of the humans who began creating fire, and as such can increase our understanding of later human evolutionary history.

Creation of fire

The ability to create fire signifies an extraordinary technological leap in human history. Humans no longer needed to depend on the chance occurrence of natural fire, or dedicate their efforts to preserving and transporting embers. If fire was desired, it could be manufactured with relative ease. With the ability to create fire at will, there would rarely be a situation in which humans had to make do without.

Although most scholars agree on the fact that the acquisition of the skills needed to produce fire, such as the ability to handle tools (Burton, 2009) and the ability to learn and replicate the processes involved (Sorenson, 2012), were significant, there tends to be some disagreement on when that transition occurred. This is because the archaeological record is often unclear in regard to the dates of and causes of fire sites and hearths (Brain & Sillent, 1998; Burton, 2009; Sorenson, 2012). Without the remains or evidence of any tools used to create fire, it is impossible to tell whether fires were manufactured or transported to the site from elsewhere.

Manufacture methods

There are two main ways in which fire can be manufactured – stone-on-stone percussion or wood-on-wood friction (Burton, 2009). There are proponents of both methods as the first to be widespread. Percussion fires may have originated accidentally as a result of normal stone toolmaking activities. However, it is much more unlikely that friction fires were created by mistake because it is not clear why early humans would have been rubbing two pieces of wood together. Friction fires, however, have an advantage in the fact that they are fairly easy to create, while stone-on-stone percussion does not easily result in fire.

Percussion fires are created by hitting two rocks or minerals (R/M) together to produce sparks. This may have arisen intentionally, or by accident while flint knapping. This method works with rocks and minerals containing iron, such as the mineral pyrite. The R/M containing iron is scratched or broken by the other R/M, exposing the iron under the surface to oxygen, which creates sparks. Percussion as a method of fire creation is not always reliable, and is only widespread today in the form of firestrikers such as flint and steel.

Although it is not likely that friction fires were accidental, there is a belief that is one of the earliest fire creation methods because it is a very simple process. Once one learns how to create a friction fire, the method is reliable and fairly simple to replicate. These methods create fire more consistently than stone on stone percussion, and tend to take less time and effort (Hough, 1890).

Friction fires can produced through multiple methods: hand drills, bow drills, pump drills, fire ploughs, and fir. Each of these methods work by grinding two pieces of wood together in order to create friction. The friction causes heat and eventually an ember that will ignite into fire when oxygen is blown onto it (Hough, 1890). There are, however, slight variations by method.

Hand drills (Figure 1) consist of a long, thin wooden shaft that is spun manually in a groove in a wooden base. The spinning and pressure generates hot, black ash that eventually forms a glowing coal. This coal is then placed among tinder that is blown on until the tinder catches fire. This method is the most widespread today.

Figure 1, Hand Drill, Image Source: (http://www.primitiveways.com/Image3/hand_drill3.jpg)

The bow drill (Figure 2) works similarly to the hand drill. The shaft is shorter and wider and is driven by a bow. This bow protects the hands and creates easier strokes, as well as additional downward pressure. The pump drill (Figure 3) is a type of bow drill that uses a coiled rope around the shaft. It allows the drill to be spun by pumping up and down.

Figure 2, Bow Drill, Image Source: (https://2rdrtx4bt29lo91s31mjhkji-wpengine.netdna-ssl.com/wp-content/uploads/2015/10/021-fire-starting-methods-bow-drill-hand-drill-method.jpg)

Figure 3, Pump Drill, Image Source: (https://i2.wp.com/cdn.makezine.com/uploads/2013/02/early-pump-drill.jpg?resize=598%2C246)

Fire ploughs (Figure 4) consist of a long wooden base with a groove cut across its length and a wooden shaft. The shaft is ground quickly against the groove with strong downward pressure. This creates hot, black ash, as with the hand drill, that becomes an ember.

Figure 4, Fire Plough, Image Source: (http://survivaltek.com/wp-content/uploads/2009/01/fireplow-hau.jpg)

Fire saws (Figure 5) use two pieces of wood and a sawing motion. One piece of wood is sawed through a notch that has been cut into another. This generates the friction needed to create an ember. This method is uncommon, found only in parts of Oceania today.

Figure 5, Fire Saw, Image Source: (https://s-media-cache-ak0.pinimg.com/originals/32/0b/0e/320b0e7e0cd541891c511dddfd4bc8f1.jpg)

The bow drill and pump drill can be discarded as candidates for early fire creation, as they both require rope in order to function, which early humans would not have had at earliest potential fire creation 1.6 Ma (Burton, 2009). Hand drills and fire ploughs are more likely, as they are more widespread today (Sorenson, 2012), though fire saws were also possible as well, as no rope is required.

Archaeological record

The archaeological record is inherently biased towards percussion methods. Wood does not preserve well in very old sites, with few exceptions. One exception is the site of Schöningen, Germany, where wooden artifacts attributed to Neanderthals have been dated to 400 – 380 ka have been found (Sorenson, 2012). Schöningen, however, is the exception, not the rule, and so friction fire tools would not likely be preserved from early fire sites. This presents a few problems. One of these problems is the inability to interpret a lack of evidence, as an absence of friction fire-making tools may indicate percussion fires, but may also indicate simply that wooden friction tools have decayed. A second issue is the inability to determine which sites were creation and which were control.

Because wood does not preserve, there is no surviving evidence of friction fires. Hearths that were the result of friction fires do not have any wooden tools remaining. This makes it impossible to determine whether these fires were the result of friction, percussion, or fire transported from another site. A lack of any fire starting tools also cannot be necessarily understood as friction fire tools that decayed. Percussion tools may have been removed and carried to another site. Fire may have been carried as an ember (Gowlett, 2016), making it difficult to know if the evidenced fire can be classified as created or controlled, due to the insufficient amount of burned materials found in the earliest fire sites, and a lack of fire-making tools remaining at most sites, regardless of dating.

Purpose of Research

The purpose of this research is to determine if human fire creation would likely arise by accident as a result of normal flintknapping. Many believe that friction fire were the first means to create fire, due its ease of use, but little research has been done as to how this happened, and as to what alternatives may have been (Burton, 2009; Gowlett, 2016). Research into this topic could tell us quite a bit about the lifestyles, and possibly even the subsequent evolution, of early humans, and how fire came to affect it.

Aimlessly setting after this question would be both daunting and unproductive, as there are a nearly limitless number of ways early humans could have discovered the ability to create fire, though some are more likely than others. So, it is likely that when fire was first created by humans, it was an occurrence that could be replicated fairly easily. It is also possible, however, that the first human-made fires were created accidentally, as the natural processes by which they may have known to create fire (e.g. lightning, volcanism) would have been impossible to recreate (Burton, 2009). If this is the case, it is reasonable to assume that such an accident would have resulted from regular activities, as the accident would have had to have occurred for the "first" time in at least a few different areas. The most likely candidate for this category is flint-knapping, as toolmaking is one of the only regular activities conducted by early humans with the potential capability of creating fire.

Striking a R/M rich in iron (as it is iron-rich R/M which create sparks) with a harder stone, such as is done in toolmaking, will create sparks. If done in proximity to a combustible material (e.g. dry brush, fur, fungus), the material may begin to smolder. This would be recognizable to opportunistic fire-users and the event could have been intentionally repeated to recreate the event.

This possibility for the creation of fire is opposed by friction methods. These methods, though needing mastery of a technique, are extremely simple, and reliably produce fires with minimal effort (Gowlett, 2016). These methods, however, require knowledge as to how fire works. It also cannot be done accidentally. Early humans will have likely had to set out to create fire in order to come across this method.

Methods

To test the possibility of accidental fire creation through percussion, flintknapping techniques were used with pyrite over straw, which functioned as the combustible. Though this experiment was done entirely with pyrite, this would not have been the only iron-rich R/M that early humans had access to, though it has one of the highest iron content at 47% (Burton, 2009). For this experiment, pyrite was chosen for two reasons: 1) It is known to throw sparks when struck, due to its high iron content, and 2) it can be found all over the world, including in parts of the East African Rift Valley. Regarding the first point, the selection of pyrite due to its ability to throw sparks should be noted, as it may have skewed results in favor of accidental toolmaking fires. Other R/M without this reputation may have been less successful than even the average of 0.18. Despite this potential bias, pyrite was chosen because its ability to throw sparks would have been an advantage that early humans may have needed in order to accidentally create fire. This experiment was done to determine if there was any possibility of accidental fire creation in stone toolmaking, and pyrite seemed like the best choice to make such fires happen. Regarding the second point, it is most likely that the ability to create fire was discovered at many different points in time at many different places around the world. Pyrite is one mineral that is common in many places around the world, including in the East African Rift Valley, where many early humans lived and evolved, as recorded in the rock record (Burton, 2009). These two points were the greatest influences in the decision to use pyrite in this experiment.

Despite these benefits to using pyrite, there were a few drawbacks that should be noted when considering the results of these experiments. One such flaw has been mentioned above, the fact that the use of pyrite may have skewed the results towards a higher average than would have other iron-rich R/M. Another flaw in the use of pyrite is that its use in the manufacture of tools is unlikely. There are no known Acheulian tools made of pyrite, and Olduwan pyrite flakes are uncommon for two reasons. First, pyrite often forms cubic crystals, making the shape unsuitable for Olduwan toolmaking. To address this in the experiments performed, only pyrite with cubic crystals about 5 mm[1] or smaller were used, so that the overall surface of the mineral would be smoother. Secondly, the production of flakes from pyrite is more difficult than with chert, basalt, or other R/M more commonly used in Olduwan toolmaking. There are no iron-rich R/M that produce flakes easily. Because of this, all iron-rich R/M are fairly unpopular choices for Olduwan flint-knapping. This fact does make accidental fire creation via percussion toolmaking even more unlikely. Because of these two factors, pyrite would not likely have been a popular choice for stone tool manufacturing. However, its common occurrence in many places means that its use was unlikely, not entirely impossible.

Although this experiment had a low average, it is likely that varying averages could be achieved with different types of R/M. Further experiments could be done with other iron-rich

[1] No exact measurements of cubic crystals were made, all judgments of size were based on estimations by eyesight alone.

R/M, and the comparison of these results could present a clearer picture in regard to whether or not accidental fire creation during toolmaking is actually feasible.

Strikes were made one at a time, with the hammerstone firmly striking the pyrite in a downward and outward motion, with the intention to create flakes, as in Olduwan toolmaking. After each set of 100 strikes, the straw was changed out, to prevent a buildup of stone debris that may have influenced the results. All sets of strikes were completed standing inside, in order to prevent the interference of variables such as wind and moisture. Each set of 100 control strikes took about 20 minutes, while each set of 100 pyrite experiments took about 30 minutes. A break of at least a half hour was taken between each 100 strikes.

As a control, 500 strikes by flint and steel have been conducted, both with and without magnesium flakes, which are a part of the flintsteel rod, and increase the possibility of combustion. The mean grade from these control experiments was compared to the mean grade of the 500 flintknapping strikes on pyrite to determine the likelihood of percussion fire creation. Strikes were done in successive trials of 100, with averages being taken for each set, and an overall average being determined from the averages of the sets.

Each individual strike was graded zero through three in spark production according to the scale below (Table 1). Sparks were visually identified, as was the determination of whether or not they reached the combustibles. The occurrence of smoke, blackened straw, flames, or any combination of the three served as indication that the combustibles caught fire.

0	No sparks created
1	Sparks created, do not reach combustibles
2	Sparks created, reach combustibles, do not catch fire
3	Sparks created, reach combustibles, catch fire

Table 1

Results

The two sequences of control came to an average of 2.68 out of 3.00 without magnesium flakes and 2.79 with magnesium flakes. The experiments with pyrite using Olduwan flint-knapping methods resulted in an average of 0.18 out of 3.00. Each trial of 100 – control without magnesium flakes (Tables 2-6), control with magnesium flakes (Tables 7-11), and experiments (Tables 12-16) – is documented in the appendix.

The tables for each 100 sets show a consistency with regard to averages over each set of 100 strikes, as illustrated in Figures 6-8. This indicates that the experimenter was consistent in their results throughout the course of the study. Should the averages have increased in each successive trial, it would indicate an improvement in skill that would have biased the experiments. Likewise, a decrease in averages with successive trials could have indicated fatigue over time. Instead, the averages remained nearly constant, with no overall increase or decrease. Human error did not play into the trials, and none of the trials were outliers.

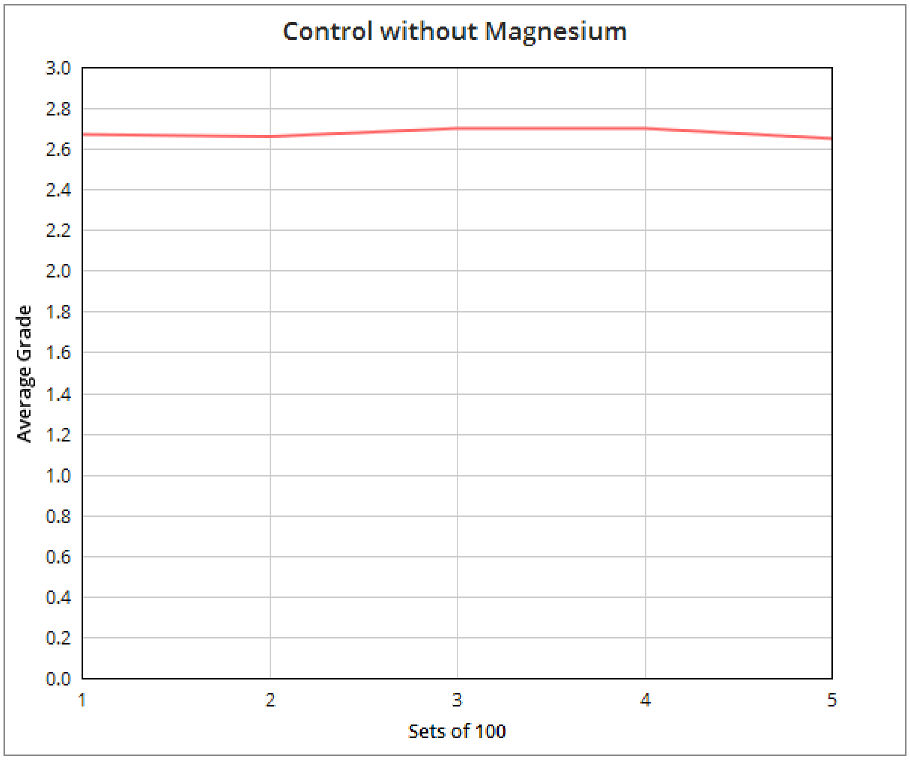

Figure 6

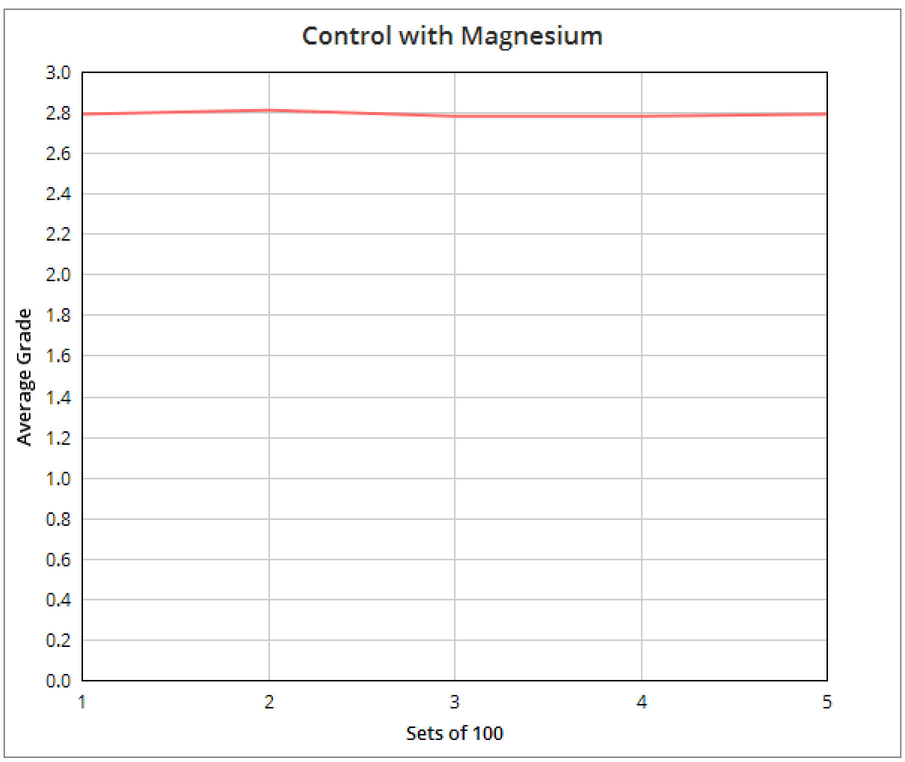

Figure 7

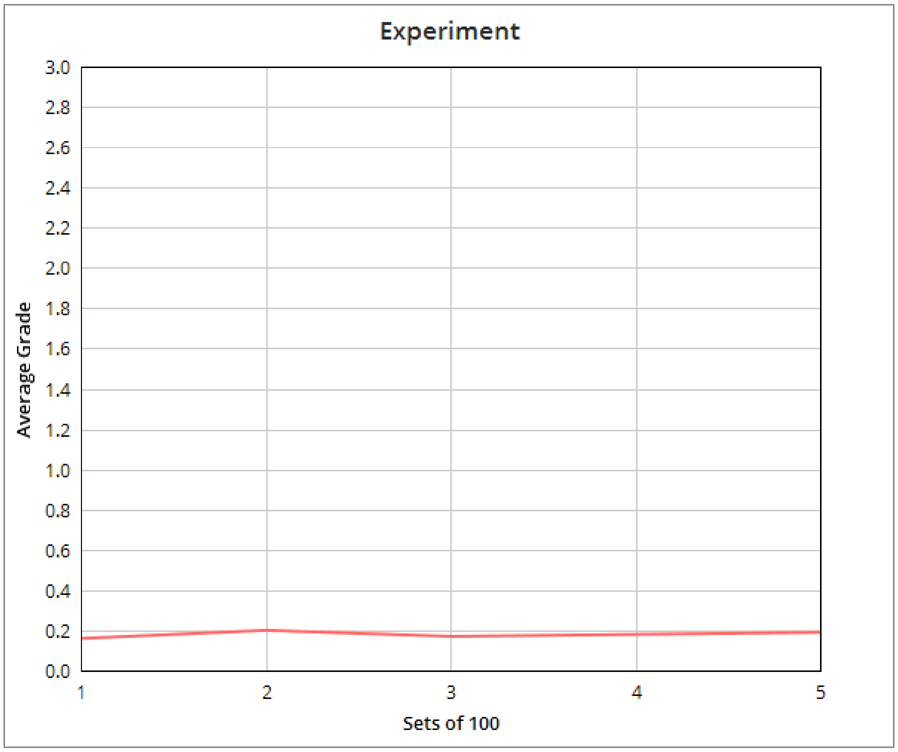

Figure 8

Under the assumption that a randomly chosen value from the data in the control without magnesium would be higher than a randomly chosen value from the experiment, the Mann-Whitney test was used to quantify and compare that relationship, with a U-value of 1730 being determined, and a significance level of 26.99, which shows that the difference is statistically significant. Run with data from the control with magnesium and the experiment, a U-value of 2440 was determined, with a significance level of 26.84, which again shows that the difference is significant. Both tests verify that the experiment significantly differed from the controls.

Discussion

The two different sets of control experiments, without magnesium flakes and with magnesium flakes, resulted in slightly different averages due to the addition of combustible magnesium in the second set of trials. However, the magnesium flakes did not affect the ability of the flintsteel to create sparks, only the fires produced when the sparks reach the combustible materials. This means any strikes graded 0 or 1 without magnesium would have been graded the same way, even with magnesium present. However, because the straw is, itself, fairly combustible, any strike with a grade of 3 with magnesium would also likely have been a 3 without magnesium. Strikes that were graded 2 without magnesium would have been the strikes most likely to have been impacted by the addition of magnesium flakes. There were still a small amount of grades of 2 in the set of control trials with magnesium, though these sparks fell and missed the piles of flakes.

Another noticeable impact of the magnesium flakes was in regard to the types of fires produced. Sparks that hit and caught the straw smoldered and burned out unless tended to, while sparks that hit the magnesium flakes created quick burning, tall flames that spread to the rest of the combustibles. Though very obvious to the eye, this did not affect the sets of trials as any and all types of fires were graded at a 3, and was therefore not taken into account in the grading system.

As with the control sets, the five sets of experiment trials stayed relatively consistent throughout the experience. There is no steady increase nor decline in the averages of the sets, which would have indicated a change in skill that could have impacted the results of the experiment.

The pyrite, though it contains iron and is known to spark, did not create many sparks. Sparks created by the pyrite tended to be fewer in number and fade faster than the showers of sparks created by the flintsteel. While the majority of strikes were graded 0, the strikes that did create sparks were most often graded at a 1, with a smaller number of strikes graded at a 2. There were no strikes graded at a 3. Any sparks that did fall and reach the combustibles did not catch fire or smolder, but extinguished.

Effects on fire creation

In this experiment, no strikes using pyrite were graded at a 3, meaning no fires were created. After 500 individual strikes, this does not definitively determine that grade 3 strikes are impossible, merely that they are highly unlikely to occur. With a mean average of 0.18, and no fires created, this leaves accidental fire creation via percussion toolmaking as highly unlikely. It would seem more likely that early humans intentionally set out to create fire via friction methods, as these are easier to master and are more reliable than percussion methods once learned.

Should these grade 3 strikes have occurred during toolmaking, it is unlikely that an early human would have been able to coax any combustibles into flames, and even unlikelier that the method would have been able to be replicated. Even less likely is it that this same method of accidental success followed by successful replication would have been achieved in many groups of early humans across the globe. The odds of one fire occurring in this manner are incredibly low, and it is nigh impossible that this method would have been the catalyst for fire creation the world over.

Conclusion

There are many factors that make early humans' discovery of fire creation by flint-knapping unlikely. The types of iron-rich R/M that throw sparks were uncommon in flint-knapping. The process would have had to have been discovered and successfully replicated many different times, in many different places in human history. It is more likely that friction fires were the original source, and that this discovery occurred later in time, when there is a greater frequency of accepted human fire sites, and when toolmaking had advanced to a point where friction fire-making becomes possible. Percussion fire creation as a whole tends to be more laborious and less reliable than friction fire creation. The one benefit that percussion has over friction fire is that early humans could discovered the process accidentally, which is far less likely for friction fire creation. Should this experiment have yielded an average closer to that of the controls, it would have been more likely that accidental fire creation in flint-knapping may have been early human's key to fire creation. However, as this experiment stands with a meager average of 0.18 out of 3.00, it is unlikely that accidental fires caused by flint-knapping occurred frequently enough to be the origin of fire creation.

Appendix

3	3	3	3	3	2	3	2	3	3
1	2	3	3	3	3	3	3	3	3
3	2	3	2	3	3	2	3	3	3
3	3	3	3	3	3	3	1	2	3
3	3	3	3	3	3	2	3	2	3
3	2	3	2	2	3	2	2	3	3
3	2	2	3	3	3	3	1	2	2
2	2	2	3	3	2	0	3	3	3
3	3	2	3	3	3	3	3	2	1
3	3	3	3	3	3	3	2	3	3

Table 2 – Control without Magnesium #1, Average 2.67

2	3	2	2	3	2	2	3	1	2
3	3	3	3	3	3	3	3	3	1
3	2	3	3	3	3	2	2	3	3
3	3	3	3	3	3	1	2	1	2
2	2	2	2	3	3	3	2	2	3
3	3	3	2	3	3	1	3	3	3
3	3	3	3	3	3	2	3	3	3
3	3	3	3	2	2	2	3	3	3
2	3	3	3	3	3	3	3	2	3
3	2	3	2	3	3	3	3	3	3

Table 3 – Control without Magnesium #2, Average 2.66

2	3	2	2	2	3	3	3	3	3
3	3	3	3	2	3	2	2	3	3
3	3	3	2	3	3	3	3	3	3
3	3	2	3	3	3	3	3	3	3
3	1	3	3	3	3	2	3	3	2
3	3	3	3	3	2	2	3	3	3
3	3	3	3	3	0	3	3	2	2
3	3	2	3	3	1	3	2	3	2
3	3	3	3	3	3	3	2	3	3
3	2	3	3	3	3	2	1	3	3

Table 4 – Control without Magnesium #3, Average 2.70

3	2	2	3	3	3	3	2	2	3
3	3	2	3	3	3	2	3	3	3
3	3	2	3	3	3	3	2	2	2
3	2	3	3	3	3	3	3	3	3
3	3	3	3	2	3	3	3	3	3
3	3	3	3	2	3	3	3	3	2
3	3	3	2	3	3	3	3	3	3
2	2	2	3	3	2	2	3	3	3
2	2	3	1	2	2	3	3	3	3
2	3	3	3	1	3	3	2	3	3

Table 5 – Control without Magnesium #4, Average 2.70

2	2	3	3	3	3	2	2	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	2	2	3	3	2	3
2	3	3	2	1	2	3	3	3	3
2	3	3	2	3	2	3	3	3	3
3	3	3	2	3	3	3	3	2	2
2	2	2	3	2	2	3	3	3	3
3	3	3	3	2	1	2	3	2	2
3	2	3	2	3	3	3	3	3	3
3	3	2	1	3	3	3	2	3	3

Table 6 – Control without Magnesium #5, Average 2.65

3	3	3	3	3	0	2	2	3	3
3	3	3	3	3	3	3	3	3	3
3	3	1	3	3	3	3	3	2	2
3	3	3	3	1	3	3	3	3	3
2	3	3	2	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3
3	3	2	3	3	3	2	3	3	3
3	3	3	3	2	3	3	3	2	3
3	3	3	3	3	3	3	3	3	3
3	1	3	3	3	2	3	3	3	3

Table 7 – Control with Magnesium #1, Average 2.79

3	3	3	3	1	3	3	3	2	1
3	3	3	3	3	3	1	3	3	3
1	2	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	2	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	1	3	3	3	3	3	2
2	3	3	3	3	3	2	3	3	3
3	3	3	3	3	3	3	3	1	3
3	3	2	3	3	3	3	3	3	3

Table 8 – Control with Magnesium #2, Average 2.81

3	3	3	3	3	1	3	3	3	3
2	3	3	3	3	3	3	3	1	3
3	3	3	3	3	3	3	3	3	3
3	1	3	3	3	3	3	3	3	3
3	3	3	3	0	1	3	3	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	2	3	3	3
2	3	3	3	3	3	1	3	3	3
3	3	3	3	3	1	3	3	3	2
3	3	3	3	3	3	3	3	3	3

Table 9 – Control with Magnesium #3, Average 2.78

1	3	3	3	3	3	3	3	3	1
3	3	3	3	3	3	3	3	2	3
3	3	3	3	3	3	3	3	3	3
3	1	3	3	3	3	3	3	3	3
0	3	3	3	3	1	3	3	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	2	2	3	3	3
3	3	3	3	3	3	1	3	3	3
3	3	3	3	3	1	3	3	3	3
3	3	2	3	3	3	3	3	3	3

Table 10 – Control with Magnesium #4, Average 2.78

3	3	3	3	3	3	3	2	3	3
3	3	3	3	3	1	0	3	3	3
3	3	2	3	3	3	3	3	3	2
1	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	2	2	1	3	3	3
3	3	1	3	3	3	3	3	3	3
1	3	3	3	3	3	3	3	3	3
3	3	3	2	3	3	3	3	3	2
3	3	3	3	2	3	3	3	3	3

Table 11 – Control with Magnesium #5, Average 2.79

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	2	0	0	0
0	0	0	0	0	1	0	0	0	0
1	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	1	1	2
0	0	0	0	0	0	0	0	0	0

Table 12 – Experiment #1, Average 0.16

0	0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	1	0	0
0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	2	0	0	1	0
0	0	2	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1	2
0	0	1	1	0	0	0	0	0	0

Table 13 – Experiment #2, Average 0.20

0	1	0	0	0	0	1	0	0	0
0	1	0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	1
1	1	0	1	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0
0	1	0	0	0	1	0	0	1	0

Table 14 – Experiment #3, Average 0.17

0	0	0	0	0	0	1	0	0	0
1	2	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0
0	0	1	1	0	0	0	0	0	1
1	0	0	0	0	1	0	0	0	0
0	0	0	0	1	0	0	0	0	0
0	1	0	0	0	0	0	0	1	0
0	1	0	0	0	1	1	0	0	0
1	0	0	0	0	0	0	0	0	0

Table 15 – Experiment #4, Average 0.18

0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	1	0	0	1	1
1	0	1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	1	0	0	0	1
0	0	1	0	0	0	0	1	0	0
0	0	0	0	1	1	0	0	0	0
1	0	0	1	0	0	0	0	0	0

Table 16 – Experiment #5, Average 0.19

Acknowledgements

Thank you to Mark Anderson for providing sources and access to materials for friction methods, Colin Betts for providing sources and information, Rebekah Gansemer for editing, and Matthew Hill for editing, revisions, providing sources, and mentoring.

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